Final Project

**Grau en Enginyeria en Tecnologies Industrials**

# Conceptual design of an electric ATV - Electric part

**REPORT**


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ETSEIB

# Abstract

This project has the aim of creating a conceptual design of the electric system of an all-terrain vehicle (ATV).

The first step has been studying the current market situation and all the technologies used in an ATV. After that, all the possible applications of an ATV have been searched and classified by sectors.

Once this information has been gathered, the product has been determined for a specific market and for a very concrete application, and the designing process has begun.

First of all, the specifications that the product will need have been defined, fixing the limits and the goals. The application to which the product is destined to has been highly taken into account in this process.

The project has proceeded with the electric design. Firstly, with a general output of the system, and later deepening into each detail and component of the product. Also in this chapter, a specific model of each pieces has been selected.

At the same time that the components have been selected, a dynamic simulator of the ATV has been used to verify that each of them assures the meeting of the specifications. Also, the simulator has been used to adjust the parameters of the components.

Once the selection of the components has been finished, an approximate 3D design of each component has been created so the possibility of assembly with the mechanic part of the ATV could be checked.

Finally, a study of the applicable legislation has been carried out, a budget has been defined and the conclusions of the project have been extracted.

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# 1. Introduction

## 1.1. Object of the project

The object of this project is the conceptual design of an electric all-terrain vehicle (ATV) to check its viability. This project will be focused in the electric and electronic part of the vehicle. Another simultaneous project, executed by Joaquim Albardaner i Torras, will be focused in the mechanical part which will complete the research.

This project will try to introduce all the necessary electric parts in the assembly of a conventional ATV. During the project, all the necessary components to achieve the correct operation and to meet with the later-on mentioned specifications, will be chosen. The components that will be used will not be designed, they are available in the market.

Specifically, the object of this project is to design an electric ATV to use for leisure ends. Later on, all the types of ATVs will be explained. The electric characteristics are adequate to make a leisure ATV of low performances. The target of this vehicle could be companies that organize family excursions in ATV through the nature. This type of client does not require high performances and being noiseless and non-contaminating could be a premium attribute for the electric ATV.

## 1.2. Justification

The decision to make an electric ATV has been motivated by several reasons. Thinking about people who like to make excursions through nature without disturbing it, the electric ATV could be a good option since it will be noiseless unlike the conventional ATVs that are disrespectful with the nature.

It is also known that pollution is a global problem and combustion engine is one of the main causer. It is for this reason that designing an ATV with an electric motor is more suitable.

Another reason is that there is no electric ATVs in the current market, and Joaquim and I want to check the viability of making a fully electric ATV with the previously mentioned characteristics.

## 1.3. Project scope

The scope of project defines the things that will be done in this research. Here you can see the key points to meet the project:

- Study the characteristics and types of current ATVs
- Conceptual design of the electric part of the ATV, always valuing the compatibility with the assembly of conventional ATV.
- Chose all the necessary electric components and justify the election.
- Simulate the vehicle with the elected components to verify the electric ATV viability, and the right selections of key components.
- Make the assembly with the mechanical part.
- Identify the legislation framework for an ATV with fully electric characteristics.
- Make a budget of what this project would cost.
- Work in harmony with Joaquim Albardaner i Torras, who is doing the mechanical part of the project.

In this project the state of art and the simulator has been done together with Joaquim Albardaner i Torras.

This project is defined as a lay-out in order to demonstrate or not the viability of an electric ATV. At the end of this project, the design phase would not be finished and should be continued.

Although this project is focused in the electric part of the vehicle, some references to mechanical parts may appear to facilitate the explanation of some chapters.

Making a real prototype will not be part of the project; this would a future point to make after finishing this first research.

# 2. State of art

Whenever a product is launched in the market, first, it is essential to make a study of the possible alternatives and competitors. Therefore, a database has been created with the documents extracted from the network.

The first and most important conclusion extracted after the analysis of information is that there are not electric ATVs in the market at this moment. This represents a good market opportunity, but in the other hand, due to not having any references in the electric ATV field, there is no existing model to evolve the design from, so this will be an extra difficulty.

Nowadays there are three types of ATVs:

- **Kid**, as the name indicates, dedicated to children between 12-16 years. It is easy identifying them by their small size, low power and small volume tank.
- **Sport,** these are ATVs dedicated to leisure. This type presents a bold and aggressive design and powerful engine, in order to move at high speeds and overcome strong slopes. However, they try to keep a low volume and a light weight to achieve maximum maneuverability and control.
- **Utility,** this type are vehicles for work, whether in the field, forest or any area of difficult terrain. They have a great power, size, and fuel tank. Also, four-wheel drive is one of its main features.


Figure 1: sport ATV and utility ATV

The principally marks who produce ATVs are Yamaha, Suzuki, Honda and Kawasaki. All these brands are consolidated marks in the motor sector.

Because the product is focused on clients who do short and relaxing excursions through moderately difficult terrains, it is thought that the vehicle has to be similar to the second category mentioned.

From the available information, only the vehicles whose category could be known were selected: kids, sport or utility.

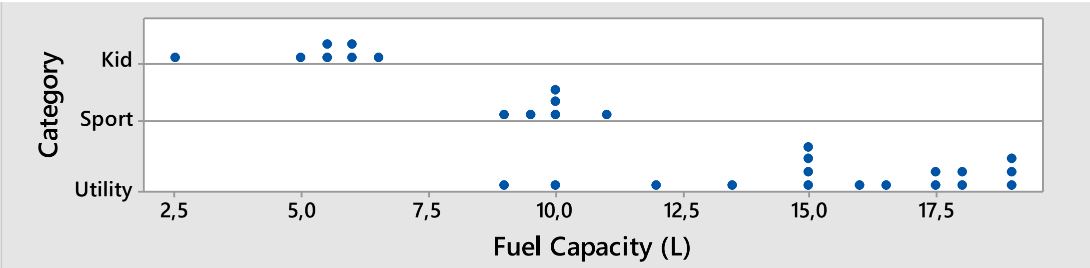



Figure 2: dot plot of fuel capacity

From figure 2 it can be concluded that the ATV will have autonomy equal to a 10L fuel tank. Approximated an ATV consumes 8L/100 km, that means 125km of autonomy. With the help of figure 3 it has been decided to make a design with 1,6 meters of length.

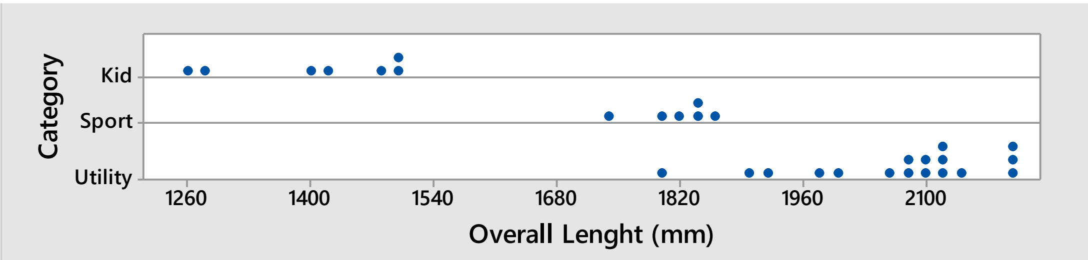



Figure 3: dot plot of overall length


Figure 4: dot plot of price

Finally, the price will have to be around 6.500 €, each component price will be included in the project. The final price of the ATV will not been calculated because our knowledge lack and available time.

## 2.1. Electrics ATVs

It has been found some electric ATVs from the kid category. They are low features vehicles and this provokes that they are indicated to use electrical technology.

Figure 5: electric ATV for kids

It was not possible to find any sport or utility electric ATV, in the nowadays market there are not electric ATVs. It has been thought that the lack of electric ATVs is due to the market size of ATVs. As it is a minority market, the marks prefer not to invest a lot in it, and develop an electric ATV represents a considerable investment. The only source that has been found is a homemade electric ATV, realized through a conventional ATV.

## 2.2. Visit to a conventional ATV

Before beginning the conceptual design and now that the basic concepts of an ATV have been learned, it has been visited a garage whose owners have two Suzuki LT - Z400. The LT - Z400 is a high performances sport ATV.

One of these ATVs is disassembled and the other is ready to be driven. The owners have allowed the examination of the ATVs. One of the owners is a mechanic and he explained the functioning of the components. Thanks to this, it has been possible to understand and see the operation of an ATV. All of the components and different parts of conventional ATV have been documented with photos. The visit has been useful to take the necessary measurements of mechanic components.

The auxiliary electric components has been listed and photographed in order to explain them later. It has been seen that some of the auxiliary components will not be necessary in the electric ATV. This non-necessary elements are related to the combustion engine.

Also, it has been done an excursion with the ATV to know the driving of the vehicle. After the visit, the knowledges about an ATV are enough to start the conceptual design.

Figure 6: two ATVs visited

# 3. General conceptual design

## 3.1. Type of ATV

It is known that an important part of vehicle users do not conceive a vehicle without a combustion engine, especially when the vehicle is used for leisure ends. Most of ATVs are focused on sport activities and the specifications of an electric ATV cannot compete with a high performance conventional ATV of this category.

It is for that reason that the electric ATV, which is going to be designed in this project, is focused on a particular target that does not need the high specifications of a combustion engine and also this same target does not like the noise of conventional ATV.

The target are companies that are dedicated to organize excursions in ATV in the nature. An ATV created for that aim will have to be easy to control, since a portion of the clients doing this type of excursions may have never driven an ATV. In this topic, an electric vehicle has the advantage that a gearbox is not necessary.

Figure 7: familiar ATV excursion through the nature

The noise generated with an electric vehicle is very low and this fact is so beneficious to do nature excursions. These excursions are usually smooth so this means that the vehicle does not need big capabilities.

The ATVs typically used by companies organizing these types of tours are utility ATVs, but it has been thought that a sports ATV can also make such excursions and could attract new customers.


Figure 8: Suzuki LT - Z400, the shape and aesthetics of the ATV will be similar to this model.

In conclusion, the ATV will not need to have incredible performances. It will be an ATV indicated to inexpert drivers and will allow to do excursions through nature in comfortable conditions and in a good speed. Also the ATV will be able to circulate on any terrain and slopes that can be found in a conventional excursion.

## 3.2. Specifications

A limit in the specifications, and also an objective, is determined to differentiate a good product from a bad one. If the objective is satisfied, the product needs will be completely covered. If a component does not meet with the limit of the specifications, it will be rejected. The specifications are exposed in the following table:

| Specifications | | | |
| --- | --- | --- | --- |
| Concept | Units | Objective | Limit |
| **Motor** | | | |
| Nominal power | kW | 12 | 7 |
| Nominal Torque | N·m | 55 | 35 |
| **Performance and consumption** | | | |
| Maximum speed | km/h | 50 | 40 |
| Acceleration to maximum velocity | s | 5 | 10 |
| Dimensions (L x W x H) | m | 1,8 x 1,1 x 0,8 | 1,8 x 1,1 x 0,8 |
| Traction | - | 4 wheels | 2 rear wheels |
| Weight | kg | 170 | 200 |
| Autonomy | km | 55 | 35 |
| **Electric system** | | | |
| Battery energy | kWh | 5 | 3 |
| Charging time | hours | 5 | 9 |
| Lights (Type) | - | Led | Led |

Once the specifications designed for the vehicle have been presented the next step is the conceptually electric design.

# 4. Electric conceptual design

In this chapter all the necessary components of an electric system will be explained and the election will be justified. The electric system is focused on meeting the wanted specifications. All the components of the ATV that power, transport or use electric energy will be considered part of the electric system. As there is no electric ATVs in the market, to define the components of an electric system an electric motorbike will be taken as a reference.

This chapter is divided in three subparts. First, all the components necessaries by the electric system will be identified. Then all the components will be explained one by one and the model and brand of each component will be decided. Finally, a general one-line diagram of the electric system of the vehicle will be showed.

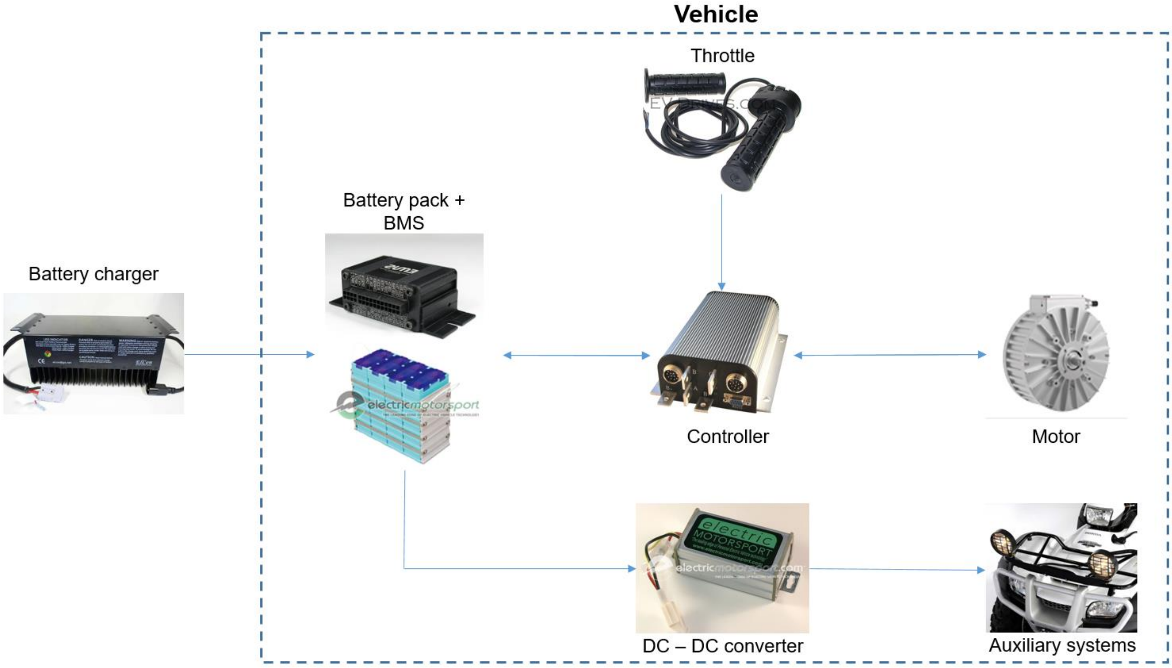



Figure 9: diagram of the electric components

Figure 9 shows a diagram of the electric components of the ATV. Through this diagram, each component will be explained and selected in the next paragraphs. Also, as the figure 9 shows, all the components are on board except for the battery charger.

## 4.1. List of components

There are many components, so they have been separated in three categories, to make the listing easier and clearer: principal, powering and auxiliary.

- Principal components: these are the most important components and they are essential for the ATV functioning.
  - Motor
  - Battery
  - Controller
  - Throttle
- Powering components: these components distribute and manage the powering of the ATV.
  - Battery Management System (BMS)
  - Battery charger
  - Wiring
- Auxiliary components: these are the electric components that all vehicles have, electrics or not.
  - DC – DC converter

## 4.2. Electric Motor

Electric motor is a machine that converts electrical energy into mechanical energy trough electromagnetic fields. There are so many types of motors, classified by their power source or their functioning.

The motor used for the ATV will be a direct current (DC) motor because the other type of motors, alternating current (AC) motors, need to be connected to power grid and that is not possible for an ATV.

An electric motor has two differentiated parts, rotor and stator. The moving part is the rotor which turns the shaft to deliver the mechanical power and the rotor could need current or not depending on if it is an electromagnet or a permanent magnet. The stator is the stationary part of the electromagnetic circuit of the motor and usually consists of either windings or permanent magnets.

### 4.2.1. DC Motor

There are two major types of DC motors differentiated by having brushes or not. Brushes are used to transmit current into the rotor. When the rotor is a permanent magnet it does not need current to rotor however it does not need brushes. The advantages and disadvantages of these two types of motors will be studied in the next chapter.

### 4.2.2. Brushless motors vs. Brushed

- **Brushless DC motor**
  - Advantages
    - Less required maintenance
    - High efficiency
    - High output power/frame size
    - Better heat dissipation
    - Higher speed range
    - Low electric noise generation
    - Simpler mechanical design
  - Disadvantages
    - Higher cost of construction
    - Control is complex and expensive
- Brushed DC motor
  - Advantages
    - Operates in extremes environments
    - High reliability
    - Low cost
    - Simple and inexpensive control
    - No controller is required for fixed speeds

- Disadvantages

  - Brush arcing generate noise
  - Speed/torque is moderately flat
  - Lower speed range due to the mechanical limitation of the brushes
  - Periodic maintenance is required
  - At higher speeds, brush friction increases, thus reducing useful torque
  - Poor heat dissipation
  - Low life-span for high intensity uses
  - Higher rotor inertia which limits the dynamic characteristics

It is obvious that the characteristics of the brushless motor are better for the solicitations of the ATV. Since the autonomy of the ATV will be a critical point of the design, it is important that the engine will be as efficient as possible and this is one of the characteristics of brushless motors. The difference in prices is acceptable, in order to improve the ATV characteristics.

### 4.2.3. Brushless motor

In the brushless motor, the rotor is a permanent magnet and stator is an electromagnet formed by coils.

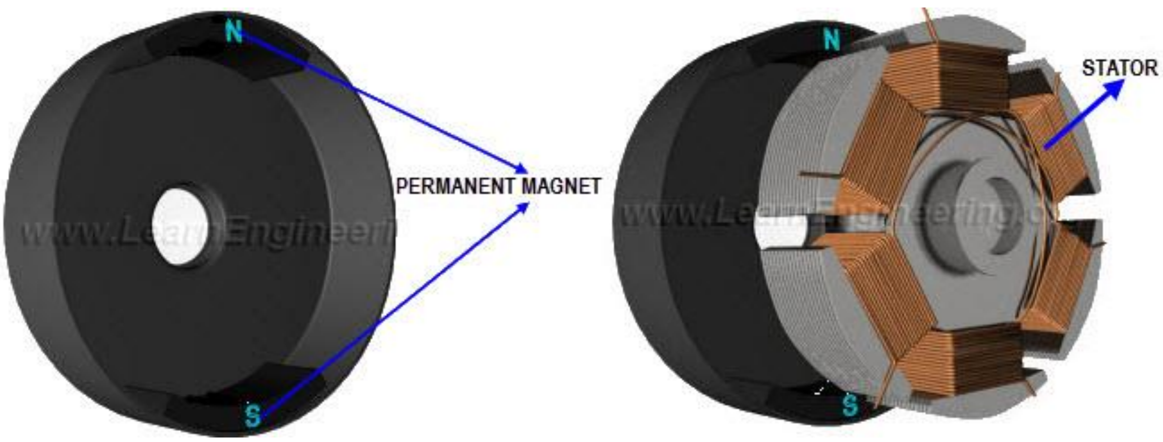



Figure 10: Rotor and stator

The movement of the rotor is generated by the magnet forces. Forces appear when current is applied into the coils, the opposite poles of rotor and stator are attracted and this provokes the movement of rotor as the movement of the motor axis that is supportive of rotor.

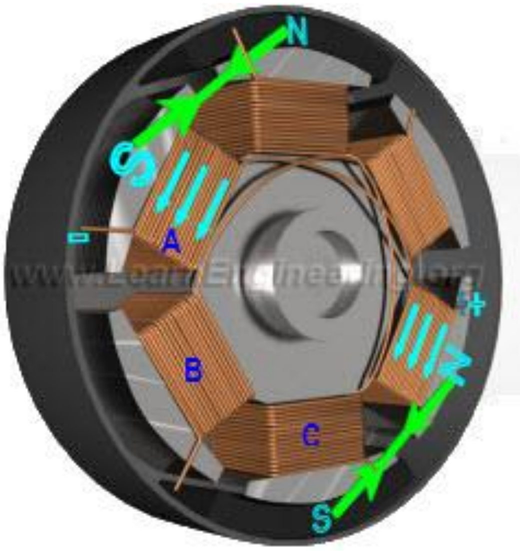



Figure 11: Attractive forces

To guarantee the movement of the rotor, the coil that is electrified varies and also its polarity. The coil that is electrified and its polarity depend on the position of the rotor. To determine which coil needs to be magnetized it is used an electronic controller, a sensor determines the position of the rotor, and based on this information the controller decides which coil to energize. This task is known as commutation.

The sensor used to determine the position of rotor uses the Hall effect. Hall effect is the production of a potential difference when an external magnetic field is applied perpendicular to the flow charge carriers. When a Hall sensor approaches a magnetic field, a proportional voltage is created, which lets you know the position of the rotor.

### 4.2.4. Motor location

The motor location in the chassis is basic to do the ATV. In an ATV with combustion engine the motor is located in the middle of the vehicle, subjected in the down central part of chassis.


Figure 12: Engine location in a conventional ATV

In prevision of the space that the batteries will need, the electric motor will not replace the space left by the engine and the other components related to the engine as the carburetor, filters, radiator, gearbox and more. The space left is reserved for the batteries because it is known that they take up a lot of space and the form factor is not optimum.

As the speed of the ATV will not be too high, it has been considered to locate the motor in the swinging arm. To verify this option, in another project, the dynamic influence of locating the motor in the swinging arm would have to be analyzed, because the motor weight is considerable.

Attending the problems of space caused by the batteries and to simplify a transmission problem, it has been decided that the motor will be located in the swinging arm, as it is wanted that the chain of transmission does not suffer extra strains due to both centers of rotation, the pinion and swinging arm, not being the same. The swinging of rear suspension would cause strains in the chain if the motor is not located in the swinging arm.

Another solution is to use an extra chain to transmit rotation in two steps. First, transmitting the rotation from the motor to swinging arm axis, and second, from the swinging arm axis to rear axis. The second solution causes more problems and it is more difficult to implement. Also, by locating the motor in the swinging arm space is gained.

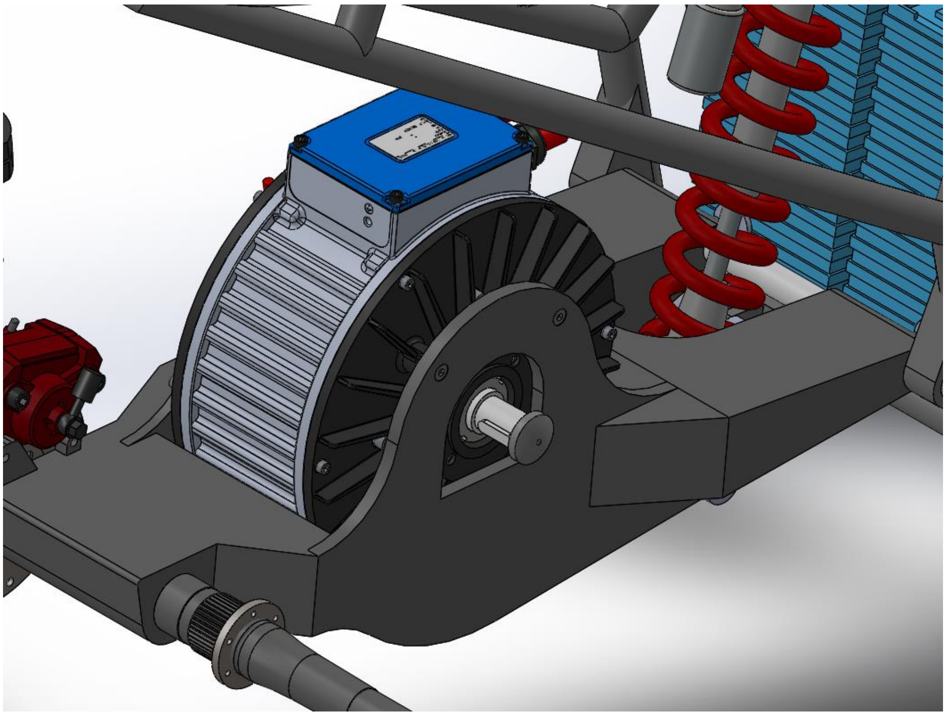


Figure 13: Motor location in the swinging arm

### 4.2.5. Motor selection

Several brands of manufacturers has been consulted and analyzed. The most relevant brands studied are:

- Agni
- Heinzamann
- Lynch
- Mars
- EV parts

To select the correct motor that it is needed it is used an Excel simulator of the ATV, the functioning of this simulator will be explained later.

The simulator allows to introduce the characteristics of one motor and seeing the reactions of the vehicle in circulation. Using the simulator and always respecting the specifications previously decided, it has been determined to select a brushless DC motor, from the brand Heinzmann, specifically the model PMS 156, which responds well to simulation and meets the required specifications.

This motor can operate in different configurations, and in the next table the final characteristics of the motor adapted to the ATV specifications are exposed.

| | |
|---|---|
| **Brand** | Heinzmann |
| **Model** | PMS 156 |
| **Type** | Brushless DC |
| **Power** | 7,2 kW |
| **Nominal speed** | 1500 $min^{-1}$ |
| **Weight** | 29,8 kg |
| **Inertia** | 58,6 $kg \cdot cm^2$ |
| **Torque constant ($K_t$)** | 0,26 Nm/A |
| **Cooling** | Air - cooled |
| **Voltage** | 48 V |
| **Nominal Current** | 176,3 A |
| **Max Stall Current** | 308 A |
| **Nominal Torque** | 45,8 Nm |
| **R** | 0,15 Ω |
| **Price** | 3.519,00 € |

Figure 14: 3D PMS 156 model

Figure 15: PMS 156

Once the motor has been selected, the measurements of the motor have been submitted to Joaquim in order to locate the motor in the swinging arm.

## 4.3. Battery

A battery is a set of electrochemical cells that can convert chemical energy into electrical energy through a chemical reaction. The advantage of a battery is that it can be recharged when it is empty. In the electric ATV a battery is needed to power the DC Brushless motor selected in the previous paragraph. It is an important election as the battery will determine the autonomy of the ATV, a very important specification of the vehicle.

| Type | Energy/ weight (Wh/Kg) | Voltage (V) | Number of recharges | Recharge time | Monthly discharge (% of total) |
|---|---|---|---|---|---|
| Pb | 30-40 | 2 | 1000 | 8-16h | 5 |
| Ni-Mh | 60-120 | 1,25 | 1000 | 2h-4h | 20 |
| Ni-Fe | 30-55 | 1,2 | 10 000 | 4-8h | 10 |
| Ni-Cd | 48-80 | 1,25 | 500 | 10-14h | 30 |
| Li-Po | 100-130 | 3,7 | 5000 | 1h-1,5h | 10 |
| Li-Ion | 110-160 | 3,7 | 4000 | 2h-4h | 25 |

### 4.3.1. Li-Ion Battery

Li-Ion batteries have a high energy density and this is a very important characteristic, as in the ATV is needed a battery as light as possible. Li-Ion batteries use, as an electrolyte, a lithium salt to generate the reversible chemical reaction between cathode and anode.

Li-Ion batteries have the following advantages:

- high energy density
- light weight
- high voltage per cell
- minimum memory effect
- lineal discharge
- long life

This are some of the most important advantages but the disadvantages also have to be considered: they are expensive and you have to be careful with overheating because they can explode. The range of work temperatures is between 10ºC and 65ºC.

With a good battery controller the problem of overheating can be solved and the price is assumable in order to improve the quality of the batteries, very important component that will considerably influence in the autonomy of the ATV.

A Li-Ion battery, like the one that would use the ATV, is formed by several cells. The charging of this type of battery has three parts:

- Constant current: during this phase, the charger applies a constant current to the battery at a steadily increasing voltage, until the voltage limit per cell is reached.

- Balance: during this phase, the charger reduces the charging current and using a balance circuit takes the cells to the same level.

- Voltage source: during this phase, the charger applies a voltage equal to the maximum battery voltage until the current is below a set limit of about 3% of initial constant charge current.

To increase the autonomy of the ATV it is needed that the battery has the maximum capacity, but always respecting the dimensions and the total weight of the ATV. Although Li-ion batteries have the best characteristics, the weight and size are considerable. This will be determinant in the decision to select the voltage and capacity. Also to decide the voltage, the motor requirements must be considered.

### 4.3.2. Battery selection

Different brands of manufacturers has been consulted and analyzed. The most relevant brands studied are:

- A123 systems
- GBS
- Winston

A simulator has been used to select the correct voltage and capacity of the battery. Also, the motor characteristics have been considered. It has been decided that 48 V and 100 Ah are good characteristics for the battery.

The cells selected for the battery are the GBS $LiFeMnPO_4$ 3,2 V 100 Ah. Sixteen cells connected in series are necessary to meet with the decided characteristics.

| | |
|---|---|
| **Brand** | GBS |
| **Chemistry** | $LiFeMnPO_4$ |
| **Voltage** | 3,2 V |
| **Capacity** | 100 Ah |
| **Dimensions** | 12,5 x 7 x 23,4 cm |
| **Weight** | 3,2 kg |
| **Cycle life** | > 1500 |
| **Operating temperature** | -20 to 65 ºC |
| **Cooling** | Air - cooled |
| **Self-discharge rate** | < 3% monthly |
| **Price of battery + BMS + battery charger** | 3.794,53 € |

Figure 16: GBS 3,2 V 100 Ah cell

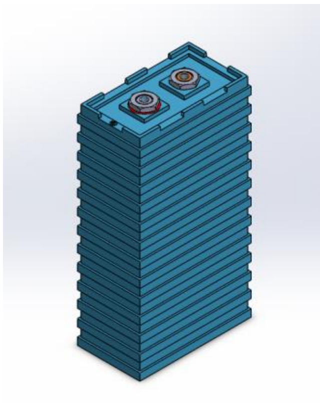


Figure 17: GBS cell 3D model

### 4.3.3. Battery assembly and location

Batteries will be the largest component in the ATV. They will be placed in the space that the engine block would occupy in a conventional ATV. The battery will be assembled in packages of four cells, four of this packages will be necessary.

Together with Joaquim it has been decided the battery position. The batteries assembly have to allow the air cooling and the pass of the wires. Also they have been symmetrically assembled.

The total weight of battery is 52,1 kg and the dimensions of one package of four cells is 12,5 x 28 x 23,4 cm. With this batteries the autonomy of the vehicle is fifty kilometres.

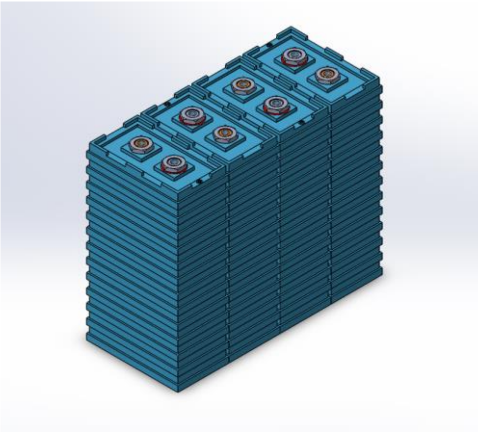


Figure 18: 4 cells package

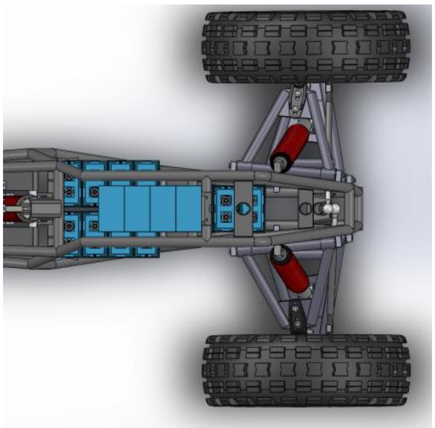


Figure 19: Batteries location in the frame (top view)

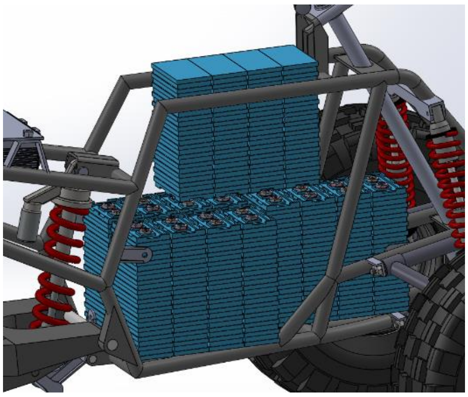


Figure 20: Batteries location in the frame (isometric view)

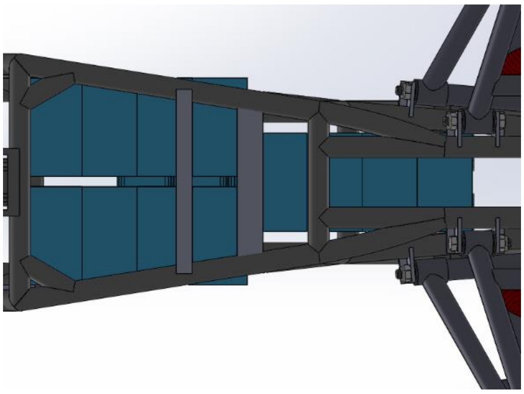


Figure 21: Batteries location in the frame (bottom view)

Once the batteries have been selected and assembled, a battery management system (BMS) is necessary to control the batteries. In the next chapter the BMS is explained. The cell structure facilitates BMS integration because it is necessary to assembly BMS sensors in the cells.

## 4.4. Battery Management System (BMS)

Most popular high performance batteries are based on Lithium chemistries. Such batteries require systems to keep them in the specified usage range while being used. The Battery Management System (BMS) is required for batteries that are sensitive to their usage conditions such as current, voltage and temperature.

A BMS is any electronic system that manages a battery pack. It can do some functions as monitoring, controlling the regenerative braking, computation, communication, protection, battery connection to load circuit and optimization.

### 4.4.1. BMS selection

The BMS selected is the Elektromotus EMUS 16 – cell BMS. Emus BMS is the product intended for use with Li-Ion, LiPO, LiFePO4 and other chemistries prismatic battery cells which operating voltages range is from 2V to 5V, in this case the cell voltage is 3,2 V . Emus BMS is a distributed type of digital BMS with central Control Unit. It does the balancing of the cells by dissipating the excess energy of cells as heat which is often referred to as passive balancing. This BMS unit is included in a pack with batteries and battery charger therefore it is supposed they are compatible. Anyway the compatibility of the components has been checked.

EMUS BMS includes BMS cell modules and dual range current sensor, this two elements give information of cells to BMS control unit.

| | |
|---|---|
| **Brand** | Elektromotus |
| **Model** | EMUS |
| **Balancing type** | dissipative |
| **Control unit supply voltage** | 7 – 20 V |
| **Dimensions** | 9,5 x 5 x 3 cm |

| | |
|---|---|
| **Optimus control unit current** | 0,5 A |
| **Weight** | 1,1 kg |


Figure 22: EMUS BMS

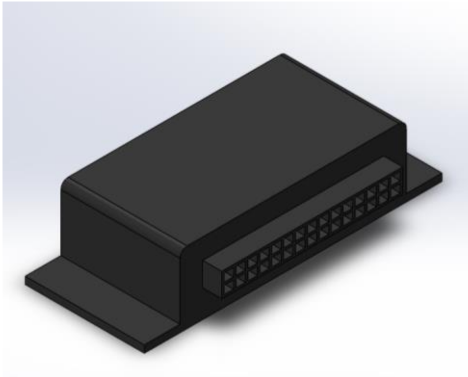


Figure 23: EMUS BMS 3D model

## 4.5. Battery charger

The battery chargers vary from 1 kW to 7.5 kW maximum charge rate. Some use algorithm charge curves, others use constant voltage, constant current. Some are programmable by the end user through a CAN port, some have dials for maximum voltage and amperage, some are preset to specified battery pack voltage, amp-hour and chemistry.

### 4.5.1. Battery charger selection

In the battery chapter, it has been explained how to charge a battery. The selected charger is the ELCON PFC 1500, which has 1,5 kW of output power. With that power, the 4,8 Kwh selected batteries will be charged approximately in 3,2 hours.This charger is included in a pack with batteries and BMS therefore it is supposed they are compatible. Anyway the compatibility of the components has been checked.

| | |
|---|---|
| **Brand** | ELCON |
| **Model** | PFC 1500 |
| **Output power** | 1,5 kW |
| **Output current** | 18 A |
| **Input voltage** | 220 V |
| **Voltage range** | 26 – 67 V |


Figure 24: ELCON PFC 1500

## 4.6. Throttle

The throttle is a simple component, it is mostly a potentiometer based on a variable resistance. The resistance value depends on the throttle position. The throttle will be connected to the controller.

Through the controller, the throttle will be able to send orders to the motor. The goal of and electric ATV throttle is the same as a conventional ATV.

The handlebar diameter and the controller must be considered when selecting the throttle. This component does not present assembly difficulties since a conventional ATV throttle is very similar.

### 4.6.1. Throttle selection

The selected throttle is the Magura twist grip. The Magura is a twist operated 5k potentiometer suitable for use with all of motor controllers. The throttle features a spring return-to-zero and will fit onto a 20-22 mm standard diameter tubular handlebar. The price of this throttle is 55,00 €.

Figure 25: Magura throttle

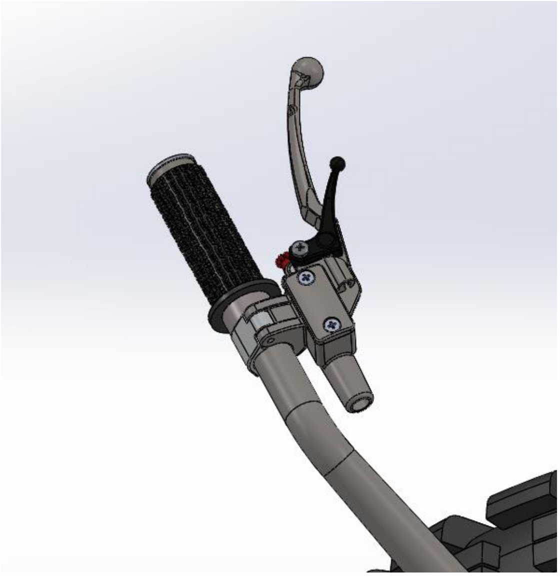


Figure 26: Magura throttle 3D model

## 4.7. DC – DC converter

There are two options In order to power the auxiliary system. On one hand, a 12 V battery and on the other, a converter. The 12 V battery is larger and weights more than the converter. For that reason, it has been decided to use a converter. The converter will turn the 48 V of the general circuit into 12 V. The converter will have a 48 V input and a 12 V output.

The converter will be placed in the front part of the frame together with the BMS. The reason why it is placed here is because it is a ventilated area. Also, being here does not interfere with the well-functioning of other components.

### 4.7.1. DC – DC converter selection

An electric MOTORSPORT DC – DC has been selected. This is a very compact and light converter, non-isolated inputs and outputs. These low cost DC to DC converters are good for 7amp circuits. Multiple units can be wired in parallel for higher output current. Three wire, Red 30-90V+ in, Yellow 12+ out, Black common.

| | |
|---|---|
| **Brand** | Electric MOTORSPORT |
| **Input** | 30 – 90 V |
| **Output** | 12 V |
| **Output current** | 10 A |
| **Power** | 120 W |
| **Weight** | 150 g |
| **Dimensions** | 8,9 x 5,1 x 3,8 cm |
| **Price** | 45,00 € |

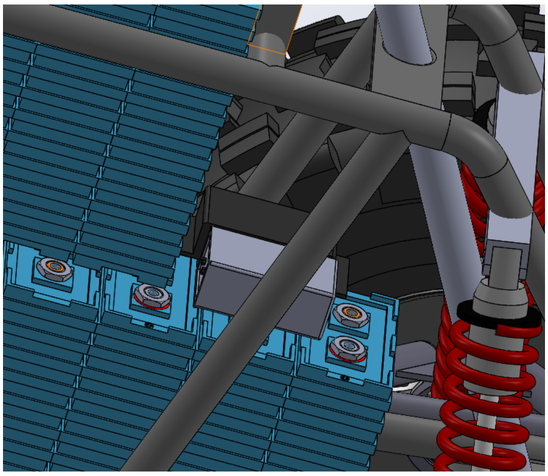


Figure 27: BMS and DC – DC converter location


Figure 28: Electric motorsport DC-DC converter

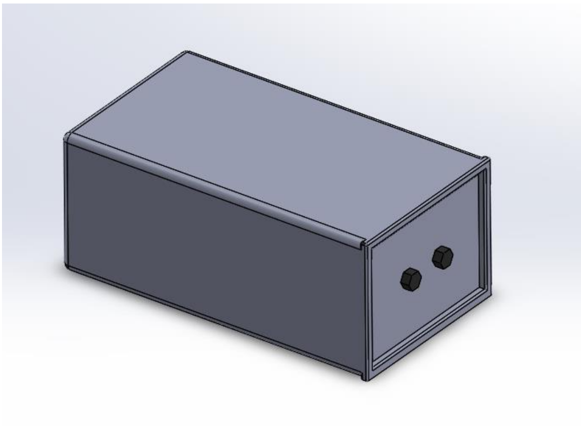


Figure 29: Electric motorsport DC-DC converter 3D model

## 4.8. Controller

In a BLDC motor, the controller makes the function of brushes. The controller needs to know the rotor orientation, relative to the coils of stator. Most controllers use a Hall effect sensor to know the position of rotor. Other motors measure the counter-electromotive force in the coils to determine the rotor position. As the motor selected incorporates a Hall sensor it will be used a controller with Hall sensor.

In a BLDC motor, two coils are energized at a time, one pushes the rotor away from it while the other attracts the rotor towards it. This increases the overall torque capacity of the motor and the Hall effect sensor determines which two coils have to be energized.

In the ATV, the controller will be between the battery and the motor. The controller receives a constant voltage from the battery and depending on the received orders through the throttle, a higher or lower voltage is sent by the controller to the motor. The controllers consist of a complex electrical circuit and have as an objective the speed and torque control. They can control the motor changing the powering voltage.

### 4.8.1. Pulse Width Modulation

Pulse Width Modulation (PWM) is a modulation technique used to control the amount of energy sent to electrical devices. In the controller, the PWM is used to convert the set 48 V of the batteries into the demanded voltage of the throttle.

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform.

### 4.8.2. Controller selection

Different brands of manufacturers has been consulted and analyzed. The most relevant brands studied are:

- Kelly controllers
- Sevcon
- Sprint Electric

The selected controller is the KBL48401E, 24V-48V, 400A, BLDC CONTROLLER/WITH REGEN. This controller allows the control of the selected motor and all the electric system. The current controller limit is superior that the motor limit, 308 A. This controller use the Hall effect sensor to know the position of the rotor.

Kelly KBL programmable BLDC motor controller provides efficient, smooth and quiet controls for the ATV. Motor speed controller uses high power MOSFET, PWM to achieve a 99% efficiency in most cases. Powerful microprocessor brings in comprehensive and precise control to BLDC motor controllers. This programmable brushless motor controller also allows users to set parameters, conduct tests, and obtain diagnostic information quickly and easily.

This controller has an optional features, one of them is the waterproof technology. That feature is essential because the ATV can go through a puddle and also can circulate under the rain. For that reason, that feature has been incorporated to the controller.

Also this controller allows the regenerative brake. This is important because if the controller is not adapted to regenerative brake, the electric system cannot use this function.

| | |
|---|---|
| **Brand** | Kelly |
| **Model** | KBL48401E |
| **Supply voltage** | 18 – 90 V |
| **Operating temperature** | -30 º to 90 º C |
| **Boost current, 10 seconds** | 450 A |
| **Motor current limit, 30 seconds** | 400 A |
| **Motor current limit, continuous** | 160 A |
| **Max battery current** | Configurable |
| **Dimensions** | 22,5 x 16,2 x 8,4 cm |
| **Price** | 359,00 € |


Figure 30: Kelly controller

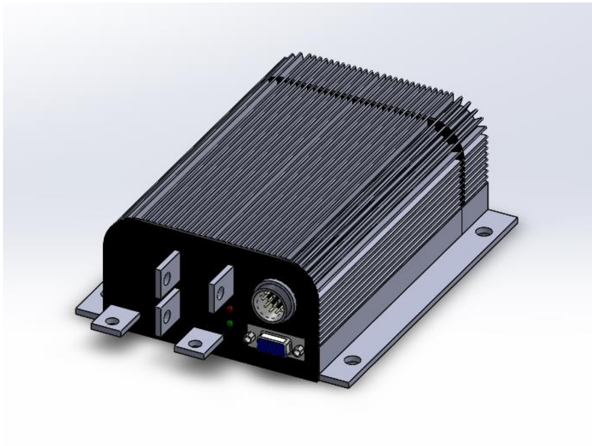


Figure 31: Kelly controller 3D model

### 4.8.3. Controller location

The controller will be located in the place where, in a conventional ATV, occupies the 12 V battery used to power the auxiliary circuit. This place is below the driver's seat. It offers great ventilation and it is safe and protected. It is important to take into account that the controller will be placed above the swinging arm. As it has been explained previously, the motor will be located in the swinging arm.

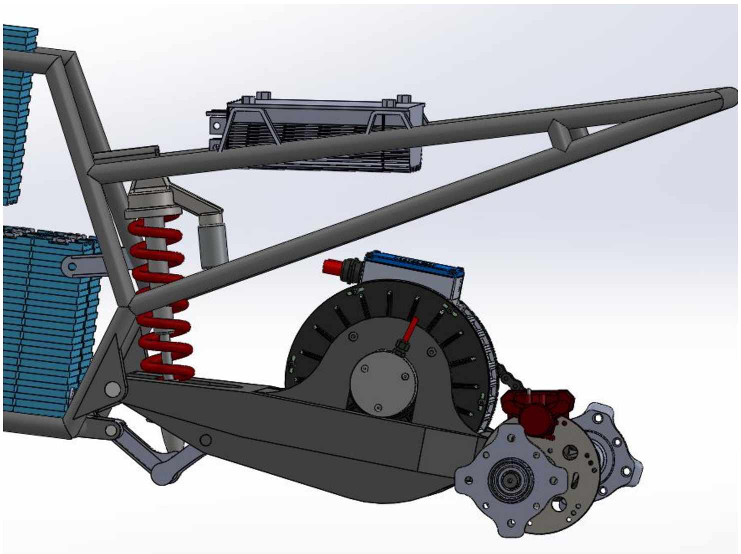


Figure 32: Kelly controller location

As the Figure 32 shows, the path of the motor, due to de swinging arm movement, could cause an interference between the motor and the controller. It is thought that the distance left is enough to avoid interferences, but in order to ensure it a particular cinematic and dynamic study of the swinging arm would be required.

## 4.9. Wiring

About the wiring, the motor and battery configuration generate a high current. High current in the electric circuit implies an accurate calculation of the thickness of wires. If the thickness is not the appropriate, overheating problems could appear.

## 4.10. General one-line diagram

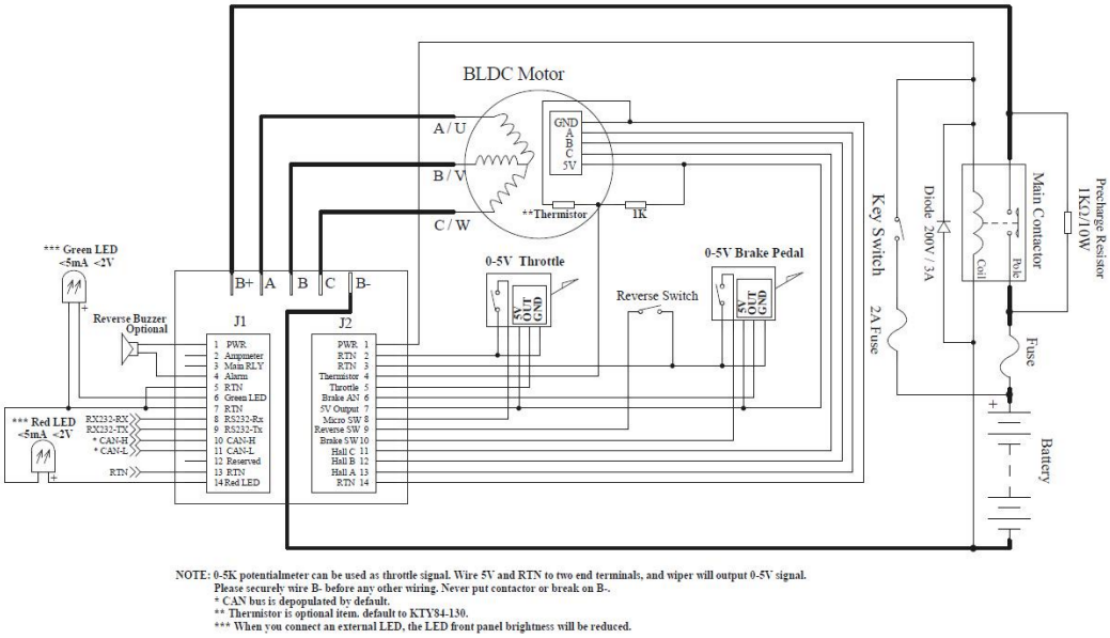


Figure 33: General one-line diagram

This diagram has been facilitated by the Kelly controllers. This is the general diagram of the components' connections. In a future project, a study would be required to find the optimum components' integration.

# 5. Dynamic simulator

The first step to design the electric ATV is preparing a simulator of the vehicle. This simulator has to return, through the independent variables and dynamic and electric equations, the dependent variables like motor current, vehicle acceleration and vehicle velocity.

This simulator has been used in order to select the correct components for the ATV. The components have been iteratively tested until the simulation has given correct results.

An Excel software is used to make this simulator. The way of working has been creating a table with all the independent variables and then introduce each equation, depending on the independent variables and time, into different columns and run the simulator trough the time to see the variation of the dependent variables.

The results appear in the rows, each row shows the results of the simulation for a time interval previously defined. To make the results easier to read, graphics of the most important and valuable dependent variables have been created depending on the time.

The simulator calculates all the dependent variables for each time interval, this time interval ($\Delta t$) is set to 0,1 seconds.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | t (s) | t (min) | Throttle ratio | V motor (V) | I motor (A) | Charge (As) | Charge (Ah) | ω motor (rad/s) | motor (rpm) | Γ motor (Nm) | Pot elec (kW) | ω wheels (rad/s) | ω wheels (rpm) | Γ wheels (Nm) | F t (N) | F r (N) | F a (N) | F p (N) | F (N) | a ($m/s^2$) | V (m/s) | V (km/h) | X (Km) |
| 2 | 0,0 | 0,0 | 1,00 | 48 | 308,00 | 30,80 | 0,01 | 0,00 | 0,00 | 80,08 | 0,00 | 0,00 | 0,00 | 240,24 | 924,00 | 134,84 | 0,00 | 0,00 | 789,16 | 3,06 | 0,00 | 0,00 | 0 |
| 3 | 0,1 | 0,0 | 1,00 | 48 | 308,00 | 61,60 | 0,02 | 3,53 | 33,70 | 80,08 | 0,28 | 1,18 | 11,23 | 240,24 | 924,00 | 134,84 | 0,08 | 0,00 | 789,08 | 3,06 | 0,31 | 1,10 | 3E-05 |
| 4 | 0,2 | 0,0 | 1,00 | 48 | 307,77 | 92,38 | 0,03 | 7,06 | 67,39 | 80,02 | 0,56 | 2,35 | 22,46 | 240,06 | 923,30 | 134,84 | 0,31 | 0,00 | 788,15 | 3,05 | 0,61 | 2,20 | 9E-05 |
| 5 | 0,3 | 0,0 | 1,00 | 48 | 301,66 | 122,54 | 0,03 | 10,58 | 101,05 | 78,43 | 0,83 | 3,53 | 33,68 | 235,29 | 904,97 | 134,84 | 0,70 | 0,00 | 769,43 | 2,98 | 0,92 | 3,30 | 2E-04 |
| 6 | 0,4 | 0,0 | 1,00 | 48 | 295,69 | 152,11 | 0,04 | 14,02 | 133,91 | 76,88 | 1,08 | 4,67 | 44,64 | 230,64 | 887,08 | 134,84 | 1,23 | 0,00 | 751,01 | 2,91 | 1,22 | 4,38 | 3E-04 |
| 7 | 0,5 | 0,0 | 1,00 | 48 | 289,87 | 181,10 | 0,05 | 17,38 | 165,98 | 75,37 | 1,31 | 5,79 | 55,33 | 226,10 | 869,62 | 134,84 | 1,89 | 0,00 | 732,89 | 2,84 | 1,51 | 5,42 | 5E-04 |
| 8 | 0,6 | 0,0 | 1,00 | 48 | 284,19 | 209,52 | 0,06 | 20,66 | 197,27 | 73,89 | 1,53 | 6,89 | 65,76 | 221,67 | 852,58 | 134,84 | 2,67 | 0,00 | 715,07 | 2,77 | 1,79 | 6,45 | 6E-04 |
| 9 | 0,7 | 0,0 | 1,00 | 48 | 278,65 | 237,38 | 0,07 | 23,86 | 227,81 | 72,45 | 1,73 | 7,95 | 75,94 | 217,35 | 835,95 | 134,84 | 3,56 | 0,00 | 697,55 | 2,70 | 2,07 | 7,44 | 8E-04 |
| 10 | 0,8 | 0,0 | 1,00 | 48 | 273,24 | 264,71 | 0,07 | 26,98 | 257,59 | 71,04 | 1,92 | 8,99 | 85,86 | 213,13 | 819,73 | 134,84 | 4,55 | 0,00 | 680,34 | 2,64 | 2,34 | 8,42 | 0,001 |
| 11 | 0,9 | 0,0 | 1,00 | 48 | 267,97 | 291,50 | 0,08 | 30,02 | 286,65 | 69,67 | 2,09 | 10,01 | 95,55 | 209,02 | 803,91 | 134,84 | 5,63 | 0,00 | 663,43 | 2,57 | 2,60 | 9,37 | 0,001 |
| 12 | 1,0 | 0,0 | 1,00 | 48 | 262,83 | 317,79 | 0,09 | 32,98 | 314,98 | 68,34 | 2,25 | 10,99 | 104,99 | 205,01 | 788,48 | 134,84 | 6,80 | 0,00 | 646,84 | 2,51 | 2,86 | 10,29 | 0,002 |
| 13 | 1,1 | 0,0 | 1,00 | 48 | 257,81 | 343,57 | 0,10 | 35,88 | 342,60 | 67,03 | 2,40 | 11,96 | 114,20 | 201,09 | 773,44 | 134,84 | 8,05 | 0,00 | 630,55 | 2,44 | 3,11 | 11,19 | 0,002 |
| 14 | 1,2 | 0,0 | 1,00 | 48 | 252,93 | 368,86 | 0,10 | 38,70 | 369,52 | 65,76 | 2,54 | 12,90 | 123,17 | 197,28 | 758,78 | 134,84 | 9,36 | 0,00 | 614,58 | 2,38 | 3,35 | 12,07 | 0,002 |
| 15 | 1,3 | 0,0 | 1,00 | 48 | 248,16 | 393,68 | 0,11 | 41,44 | 395,77 | 64,52 | 2,67 | 13,81 | 131,92 | 193,57 | 744,49 | 134,84 | 10,74 | 0,00 | 598,91 | 2,32 | 3,59 | 12,93 | 0,003 |
| 16 | 1,4 | 0,0 | 1,00 | 48 | 243,52 | 418,03 | 0,12 | 44,12 | 421,34 | 63,32 | 2,79 | 14,71 | 140,45 | 189,95 | 730,56 | 134,84 | 12,17 | 0,00 | 583,55 | 2,26 | 3,82 | 13,77 | 0,003 |
| 17 | 1,5 | 0,0 | 1,00 | 48 | 239,00 | 441,93 | 0,12 | 46,73 | 446,26 | 62,14 | 2,90 | 15,58 | 148,75 | 186,42 | 716,99 | 134,84 | 13,65 | 0,00 | 568,50 | 2,20 | 4,05 | 14,58 | 0,003 |
| 18 | 1,6 | 0,0 | 1,00 | 48 | 234,59 | 465,39 | 0,13 | 49,27 | 470,54 | 60,99 | 3,01 | 16,42 | 156,85 | 182,98 | 703,77 | 134,84 | 15,18 | 0,00 | 553,75 | 2,15 | 4,27 | 15,37 | 0,004 |
| 19 | 1,7 | 0,0 | 1,00 | 48 | 230,30 | 488,42 | 0,14 | 51,75 | 494,18 | 59,88 | 3,10 | 17,25 | 164,73 | 179,63 | 690,90 | 134,84 | 16,74 | 0,00 | 539,31 | 2,09 | 4,49 | 16,15 | 0,004 |
| 20 | 1,8 | 0,0 | 1,00 | 48 | 226,12 | 511,03 | 0,14 | 54,16 | 517,21 | 58,79 | 3,18 | 18,05 | 172,40 | 176,37 | 678,35 | 134,84 | 18,34 | 0,00 | 525,18 | 2,04 | 4,69 | 16,90 | 0,005 |
| 21 | 1,9 | 0,0 | 1,00 | 48 | 222,05 | 533,23 | 0,15 | 56,51 | 539,64 | 57,73 | 3,26 | 18,84 | 179,88 | 173,20 | 666,14 | 134,84 | 19,96 | 0,00 | 511,34 | 1,98 | 4,90 | 17,63 | 0,005 |
| 22 | 2,0 | 0,0 | 1,00 | 48 | 218,08 | 555,04 | 0,15 | 58,80 | 561,48 | 56,70 | 3,33 | 19,60 | 187,16 | 170,11 | 654,25 | 134,84 | 21,61 | 0,00 | 497,80 | 1,93 | 5,10 | 18,34 | 0,006 |

Figure 34: Excel simulator

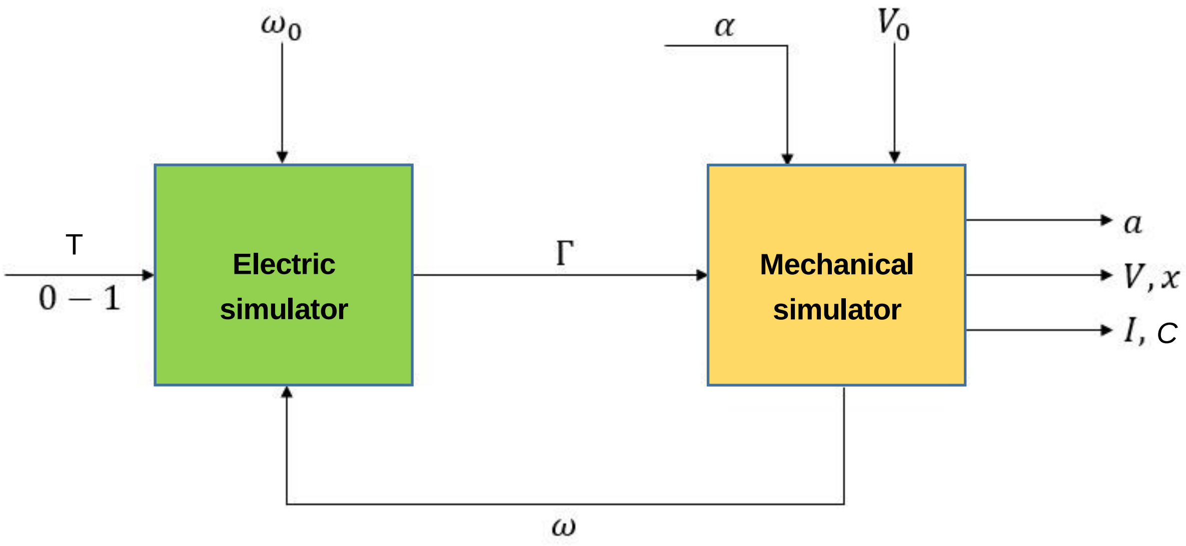



Figure 35: Diagram of the functioning of simulator

## 5.1. Equations

In this chapter all the necessary equations to process all the variables introduced in the simulator and the results will be explained. There are electric equations, to simulate the motor running and mechanical equations to simulate the reactions of the vehicle to the functioning motor.

### 5.1.1. Electric equations

- $V_{motor} = T \times V_{battery}$
- $I_{motor} = \frac{V_{motor} - (K_t \times W_{motor})}{R}$
- $C = \frac{I_{motor} \times \Delta t}{3600}$
- $W_{motor} = \frac{W_{wheels}}{i}$ , initiated into zero
- $\Gamma_{motor} = K_t \times (I_{motor} - I_0)$
- $P_{elec} = \frac{\Gamma_{motor} \times W_{motor}}{1000}$

### 5.1.2. Mechanical equations

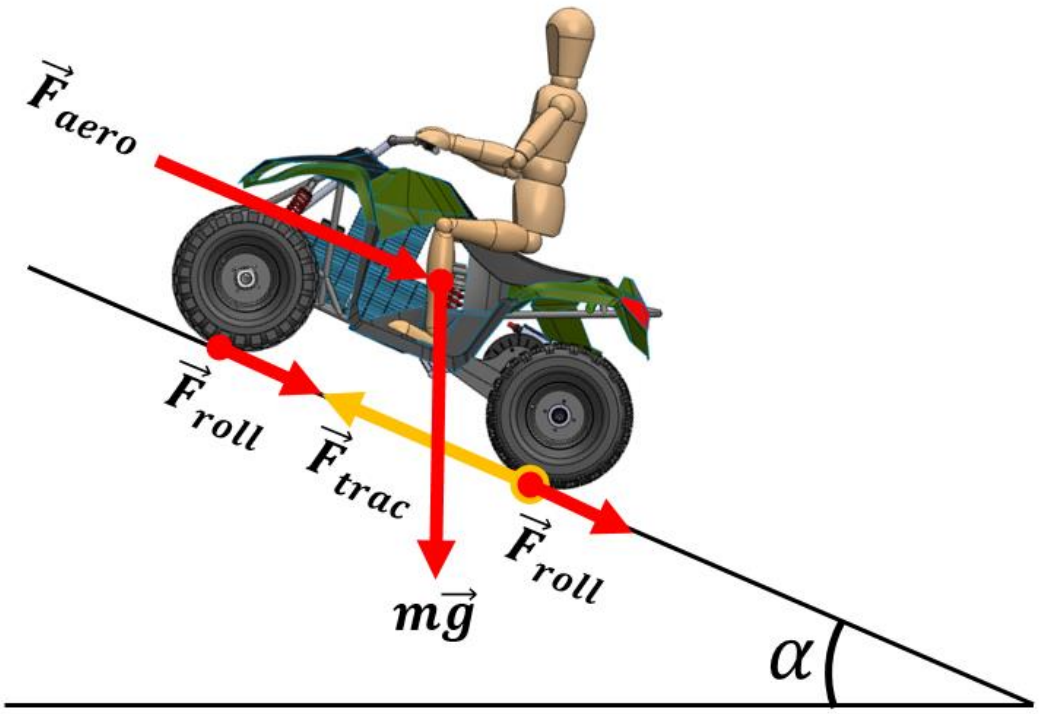



Figure 36: Diagram of the forces

- $W_{wheels} = \frac{V}{r}$
- $\Gamma_{wheels} = \frac{\Gamma_{motor}}{i}$
- $F_{trac} = \frac{\Gamma_{wheels}}{r}$
- $F_{roll} = m \times g \times \cos\alpha \times C_{rr}$
- $F_{aero} = \frac{1}{2} \times C_d \times S_n \times \rho \times V^2$
- $F_w = m \times g \times \sin\alpha$
- $F = F_{trac} - F_{roll} - F_{aero} - F_w$
- $a = \frac{F}{m + \frac{Jr}{i \times r} + \frac{Jw1}{r} + \frac{Jw2}{r}}$
- $V = a \times \Delta t \times 3{,}6$
- $X = (V \times \Delta t) + \frac{1}{2} \times a \times \Delta t^2$, initiated into zero

## 5.2. Independent variables

In this chapter, all the variables that are necessary to run the simulator will be explained. There are electric variables, principally related with the motor, batteries and controller, mechanical variables and external conditions like the slope of the road.

### 5.2.1. Electric independent variables

- Battery voltage – $\mathbf{V_{battery}}$ [V].
- Intern motor resistance – **R** [Ohms], motor winding resistance.
- Torque constant of motor – $\mathbf{K_t}$ [Nm/A], this is an own constant of motor. This constant is equal that $K_c$ constant. It has been demonstrated in Annex C
- Motor $\mathbf{I_0}$ [A], it is the minimum current to start de engine.
- Current limit [A], maximum current that motor can support during few seconds.
- Throttle – **T**, this number is defined between zero and one. This number determines the voltage that the batteries deliver to the motor. Simulate the vehicle throttle.

### 5.2.2. Mechanical independent variables

- Motor rotor inertia – $\mathbf{J_r}$ [kg·m$^2$].
- Gear ratio between motor axle and traction axle – **i**.
- Wheels inertia – $J_w$ [kg·m$^2$], in this value is included the inertia of all other rotating parts like axle or brake disc. $\mathbf{J_{w1}}$ and $\mathbf{J_{w2}}$, the first from front axle and second from the rear axle.
- ATV weight – **m** [kg].
- Normal surface to movement of ATV – $\mathbf{S_n}$ [m$^2$], this value will be used to calculate the aerodynamic force.
- Rolling resistance – $\mathbf{C_{rr}}$, this constant depends on the wheels and the terrain.
- Traction wheels radius – **r** [m].
- Aerodynamic resistance coefficient – $\mathbf{C_d}$, this constant depends on the shape of the ATV.
- Initial vehicle speed – $\mathbf{V_0}$ [m/s], considered zero.
- Initial motor speed – $\mathbf{W_0}$ [rad/s], considered zero.

### 5.2.3. External conditions

- Air density – $\boldsymbol{\rho}$ [kg/m$^3$].
- Slope – $\boldsymbol{\alpha}$ [rad].
- Gravity – **g** [m/s$^2$].

## 5.3. Dependent variables

In this chapter, the most important and valuable dependent variables that will result from the simulation will be explained. Two types of variables are important, the variables which allow to control the limits of the components, like the motor speed, and the variables which allow to see the performance of the vehicle like acceleration or speed of the ATV.

### 5.3.1. Electric dependent variables

- Motor voltage – $\mathbf{V_{motor}}$ [V].
- Motor current – $\mathbf{I_{motor}}$ [A], this variable allows control that the current does not pass the allowed limit.
- Electric charge burned by motor – **C** [Ah], this variable allows control the battery level.
- Motor speed – $\mathbf{W_{motor}}$ [rad/s], this variable allows control that the speed does not pass the allowed limit.
- Motor torque – $\mathbf{\Gamma_{motor}}$ [N·m].
- Electric power – $\mathbf{P_{elec}}$ [kW].

### 5.3.2. Mechanical dependent variables

- Wheels speed – $\mathbf{W_{wheels}}$ [rad/s].
- Wheels torque – $\mathbf{\Gamma_{wheels}}$ [N·m].
- Traction force – $\mathbf{F_{trac}}$ [N].
- Rolling force – $\mathbf{F_{roll}}$ [N].
- Aerodynamic force – $\mathbf{F_{aero}}$ [N].
- Weight force – $\mathbf{F_{w}}$ [N].
- Resultant force – **F** [N].
- Vehicle acceleration – **a** [m/s$^2$].
- Vehicle speed – **V** [km/h].
- Traveled distance – **X** [km].

## 5.4. Imposed conditions

### 5.4.1. Current limit

The current limit, set by the motor characteristics, has been introduced into the simulator with a simply conditional formula. Formula “if” of Excel has been used to program the condition.

When the current that arrives at the motor overcomes the limit, the conditional formula changes the value by the limit value. This limit allows to control the overheating of the motor. Either if the current is positive or negative, the formula changes the value keeping the sign.

This function in the ATV is implemented by the controller. The controller can be programed to different current limits. It has been considered that the controller can endure the maximum current. The maximum current in the ATV electric circuit will be 308 A.

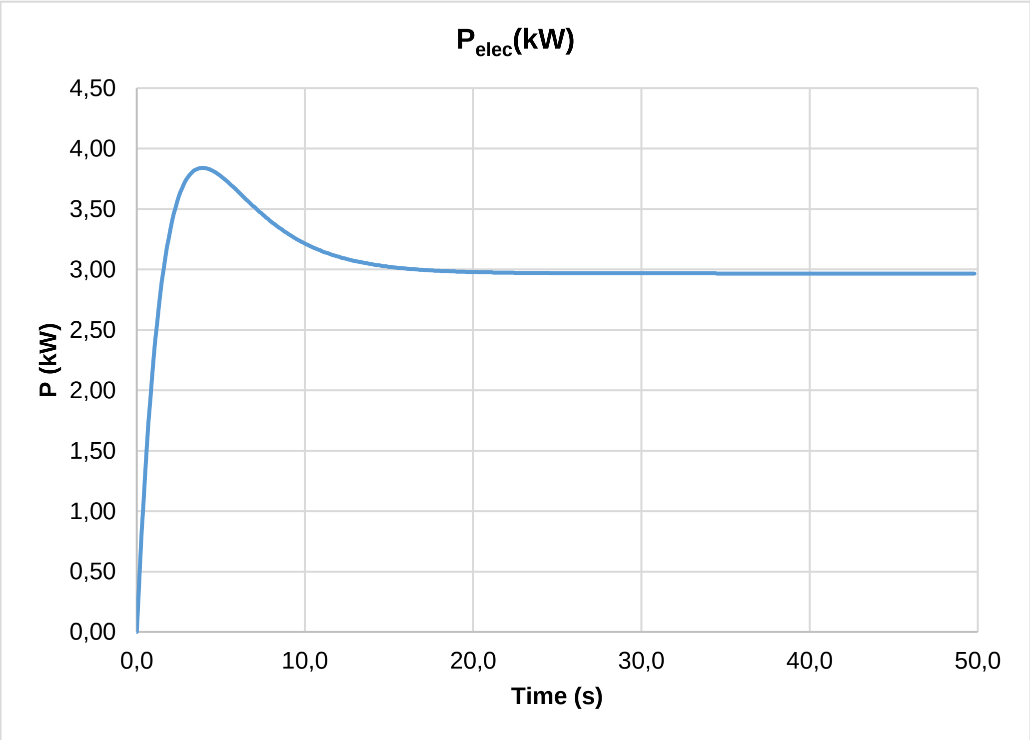



Figure 37: $P_{elec}$ graphic

### 5.4.2. Total force

When the vehicle is starting, the traction force is not enough to overcome the rolling force. That fact causes a negative total force as well as a negative acceleration. When the vehicle is still, the negative acceleration induces the vehicle to go backwards.

A conditional formula has been introduced using the formula “if” of Excel to solve that problem. The set condition is that when the force is negative and the vehicle speed is zero, the conditional formula changes the force value into zero. The zero speed condition has been introduced in order to enable breaking. To break, the total force has to be negative but only when the vehicle is moving.

### 5.4.3. Regenerative brake

When the vehicle is moving and the throttle ratio decreases, current automatically becomes negative. As the current is negative, the electric charge wasted in this time interval is negative. An electric negative charge means that in this time interval the battery has been charged. This allows to extend the battery life.

## 5.5. Simulation results

Once all the independent variables of the simulator that depend on the electric components have been set, the only parameters that have not been set are the transmission ratio, the slope and the throttle ratio. The slope and the throttle ratio do not have to be set, this two parameters allow to generate different situations in the simulator. In the other hand, the transmission ratio has to be set because it is an element that has to be assembled in the ATV and only can take one value.

### 5.5.1. Transmission ratio

The transmission ratio affects the relation between motor torque and wheels torque. A simulation with a set throttle ratio and a set slope has been prepared. The throttle ratio has been maximized, it means that the acceleration of the ATV is maximum and the slope has been set in zero. In this conditions, the value of transmission ratio has been varied until a correct value has been found that meets the specifications. The correct found value is $i = 1/3$. Using that ratio the maximum speed is 40 km/h and the time to achieve this maximum speed is nine seconds.

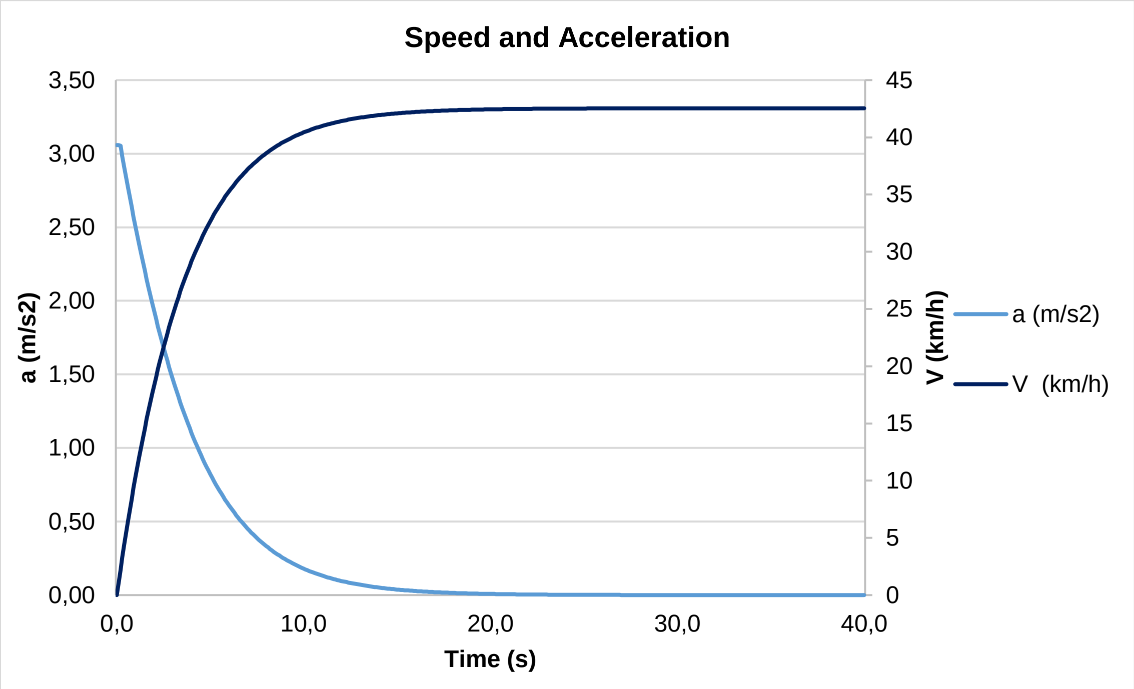



Figure 38: Speed and acceleration graphic

### 5.5.2. Slope

Now with all the variables set, a several simulations incrementing the value of slope have been done. The limit slope that the ATV can overcome has been found in seventeen degrees. The maximum speed in this slope is six km/h and the time to achieve the maximum speed is thirteen seconds.

### 5.5.3. Autonomy

The autonomy of the vehicle has been found simulating a real circuit. The circuit has been generated with different slopes and throttle ratios trying to simulate a real driving experience. Also, it has been considered that the vehicle will not be able to continue when the batteries are wasted. It has only been considered the 80% of the capacity of the batteries. This percentage is enforced due to the lack of accuracy of the value given by the manufacturer. The final autonomy result is fifty kilometers.

### 5.5.4. Final specifications

| Specifications | | | | |
|---|---|---|---|---|
| Concept | Units | Objective | Limit | Achieved |
| **Motor** | | | | |
| Nominal power | kW | 12 | 7 | 7,2 |
| Nominal Torque | N·m | 55 | 35 | 45,8 |
| **Performance and consumption** | | | | |
| Maximum speed | km/h | 50 | 40 | 40 |
| Acceleration to maximum velocity | s | 5 | 10 | 9 |
| Dimensions (L x W x H) | m | 1,8 x 1,1 x 0,8 | 1,8 x 1,1 x 0,8 | 1,88 x 1,22 x 0,77 |
| Traction | - | 4 wheels | 2 rear wheels | 2 rear wheels |
| Weight | kg | 170 | 200 | 180 |
| Autonomy | km | 55 | 35 | 50 |
| **Electric system** | | | | |
| Battery energy | kWh | 5 | 3 | 4,8 |
| Charging time | hours | 5 | 9 | 5 |
| Lights (Type) | - | Led | Led | Led |

# 6. General assembly

In the general assembly, both parts of the project have been put together: the mechanical and electric. Some parts of the assembly have been conceptually designed and should be recalculated in a future project. The goal was to create an overall pleasant and non-aggressive image of the ATV. The green color has been selected since the electric ATV is respectful with the nature and would be a commercial way to highlight its commitment with the environment.

At the general assembly, a dummy has been incorporated in order to check that the pilot position is correct. As shown in the Figure 39, the dummy sits in an ergonomic position.

Figure 39: General assembly with bodywork and dummy

In the figures 40 and 41, the bodywork and the dummy have been hidden in order to show all the components inside the ATV.

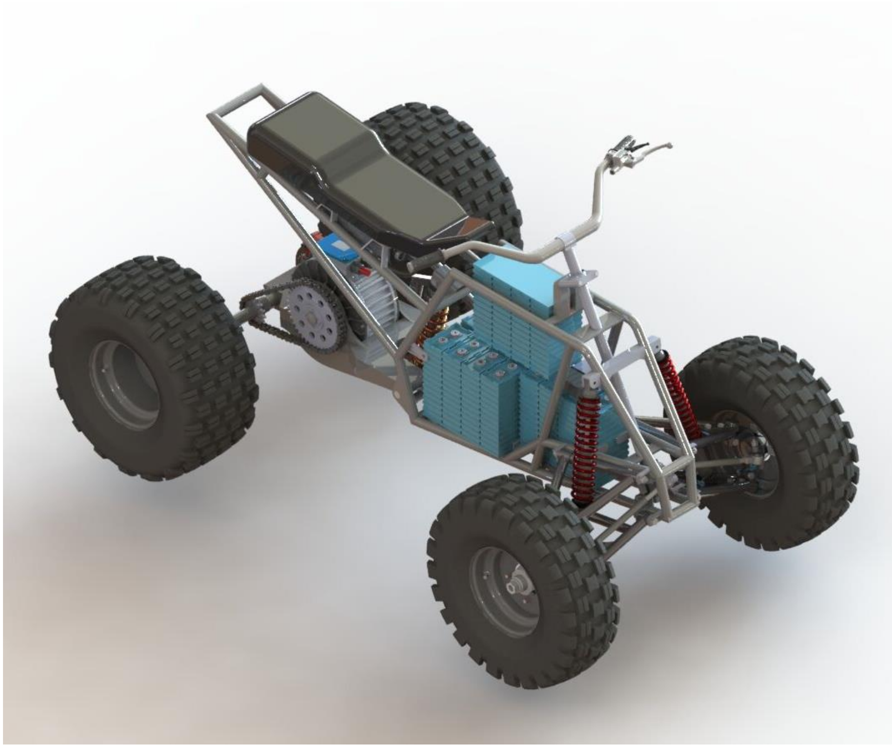


Figure 40: General assembly, inside view.

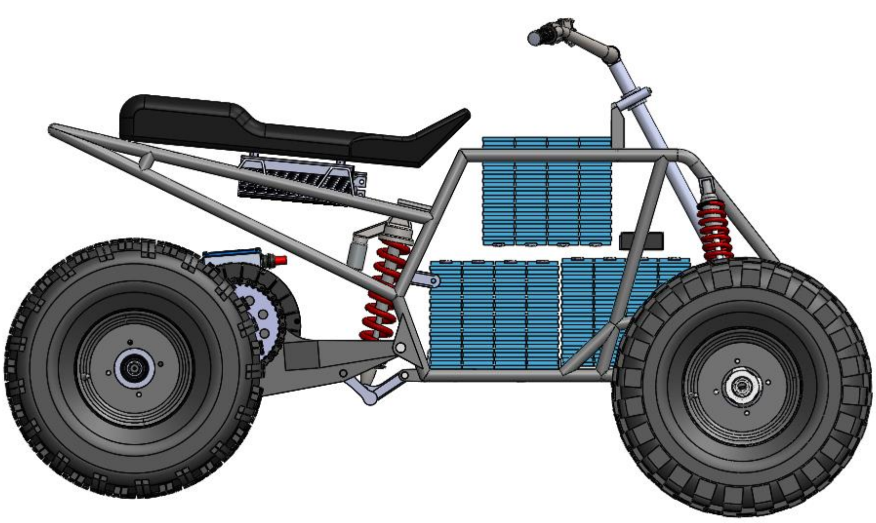


Figure 41: General assembly, lateral view.

# 7. Legislation

The final vehicle must be registered to be able to circulate. For this purpose it has to decide in which category.

| Category | Maximum weight (kg) | Maximum power (kW) | Accessible roads |
|---|---|---|---|
| **Light quadricycle** | 350 | 4 | All except highway |
| **Quadricycle** | 550 | 15 | All |
| **Especial vehicle** | - | - | All if the vehicle goes at least 60km/h |

The ATV must be registered as a special vehicle because the maximum speed is 40 km/h

| | License | License plate | Use of helmet | ITV | Speed limit |
|---|---|---|---|---|---|
| **Special vehicle** | B | White background with red characters | No | From 4 to 10 years: biennial. Over 10 years: annual. | 70 km/h |

So, the driver must have license B. Also the ATV must have:

- Technical sheet of the vehicle and chassis number.
- The vehicle must meet the size and dimensions contained in the technical sheet.
- The tires must have the dimensions and pressure of the technical sheet and be in good conditions.
- Brakes perfectly functional.
- Mirrors in good condition
- Support for registration and a plate of maximum speed at the rear of the vehicle.
- Odometer.
- Lights homologated.
- Blinkers visible and without any interference at a bigger angle than 10º.

# 8. Environmental impact

In this chapter the yearly generated $CO_2$ has been approximately calculated. It has been considered that in the application of the ATV, the battery is recharged six times per week. In order to make the result of this calculation more meaningful, also it has been calculated the yearly generated $CO_2$ of a conventional ATV in the same conditions. It has been considered double autonomy for the conventional ATV.

- Electric ATV:

| Battery energy (kWh) | Weekly refills | Yearly energy (kWh/year) | Spain electricity conversion factor ($CO_2$kg/kWh) |
|---|---|---|---|
| 4,80 | 6 | 1.497,60 | 0,33 |

Yearly generated $CO_2$ = 1.497,60 kWh/year x 0,33 $CO_2$kg/kWh = **494,21 kg of $CO_2$ /year**

- Conventional ATV (gasoline engine):

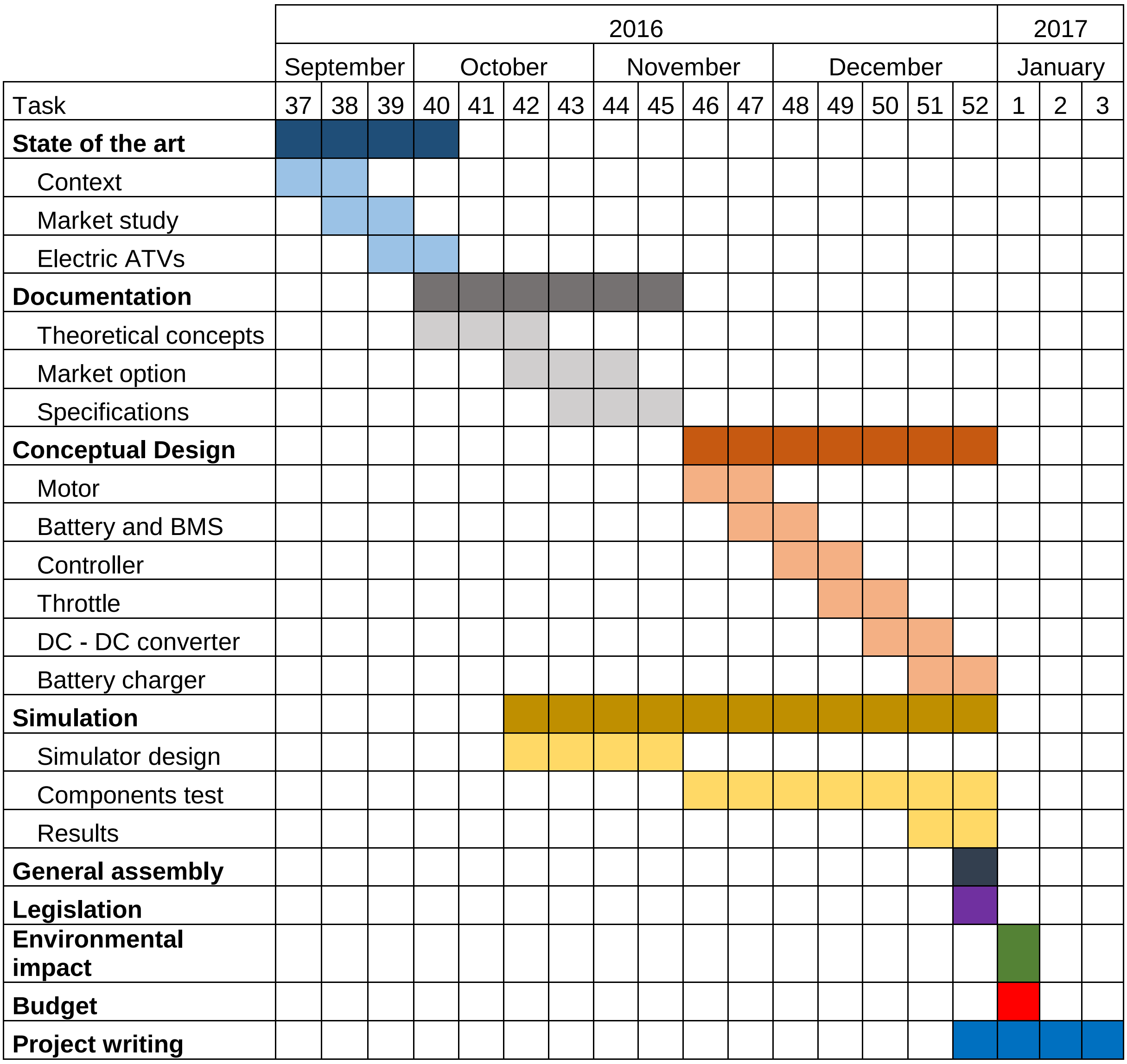
| Fuel capacity (L) | Weekly refills | Yearly volume (L/year) | Gasoline conversion factor ($CO_2$kg/L) |
|---|---|---|---|
| 10,00 | 3 | 1.560,00 | 2,19 |

Yearly generated $CO_2$ = 1.560,00 L/year x 2,19 $CO_2$kg/L = **3.416,40 kg of $CO_2$ /year**

As you can see the $CO_2$ generated is seven times more elevated in a conventional ATV than in an electric ATV.

# 9. Planning

The planning of the tasks that will be done in the project has been elaborated. It has been used a Gantt diagram with a week as a time unit.



# 10. Budget

In this chapter a budget about the hours inverted in the project has been done. The budget has divided in the different realized tasks.

| Concept | Quantity | Unit price | TOTAL |
|---|---|---|---|
| Hours doing the state of the art | 20 | 30,00 € | 600,00 € |
| Hours of documentation | 100 | 30,00 € | 3.000,00 € |
| Hours of conceptual design | 90 | 70,00 € | 6.300,00 € |
| Hours of simulation | 50 | 45,00 € | 2.250,00 € |
| Hours of drawing | 30 | 50,00 € | 1.500,00 € |
| **TOTAL** | | | **13.650,00 €** |

# Conclusions

After this first contextualization stage, it can be concluded that it is perfectly possible to build fully electric ATVs. However the product is far from being complete and to perfect it, it would be necessary to do:

- A finite elements study, to make sure that the frame does not bend under the battery weight.
- A thermal study, to assure that no parts overheat, like the batteries, the controller or the motor.
- Another finite elements study of the swinging arm to make sure it can resist the impacts.
- A stability study of the rear suspension in order to determine the constant of the string and shock absorber that assure that the motor weight increment does not destabilize the system.
- A study to define another voltage to the batteries because the voltage is too low and this creates a high current and limit the motor power.

The mentioned key points are only some examples of what should be done in a future project. With the selected components, the specifications have been met. In some specific case, the limit has almost been overcame.

During the project, we have learned the steps that need to be followed in order to design a product. We initially did not have a conventional ATV 3D model, which was a difficulty. This has meant we had to do all the 3D model design from scratch, when our initial intention was to start from an existing conventional 3D model and only modify the affected parts of the electric transformation.

This has not allowed us to deepen on the parts we would have liked to, but has allowed us to have a more general vision of the ATV and learn all of its components.

Finally, I would like to acknowledge my partner and friend Joaquim Albardaner i Torras for agreeing to do the project with me. Without his support and dedication, it would not have been possible to carry out the project.

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